IMPACT: A Parallel Beam Dynamics Code with Space Charge

Robert D. Ryne
Lawrence Berkeley National Laboratory

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Performed in Collaboration with

- J. Qiang, LBNL
- Viktor Decyk, UCLA
- Salman Habib, LANL

IMPACT: Integrated-Map and Particle Accelerator Tracking Code

- **Originally developed to model beam dynamics with space charge in linacs**
- **One goal: develop improved model of beam dynamics in rf cavities; done by treating rf cavities w/ same map-based techniques used to model other z-dependent elements (e.g. quads w/ fringe fields)**
  - Obtain single particle Hamiltonian H_{ext}, then numerically integrate linear equations for linear map: dM/dT=JSM
    - ✔ Requires knowledge of E(z) on axis and dE/dz
  - Note well: must also integrate equations for the design trajectory

IMPACT computes reference trajectory and maps around that trajectory "on the fly"

- **Key elements of IMPACT are:**
  - Map-generation capabilities
  - 3D parallel Poisson solvers
  - Particle manager to reduce communication and obtain high performance

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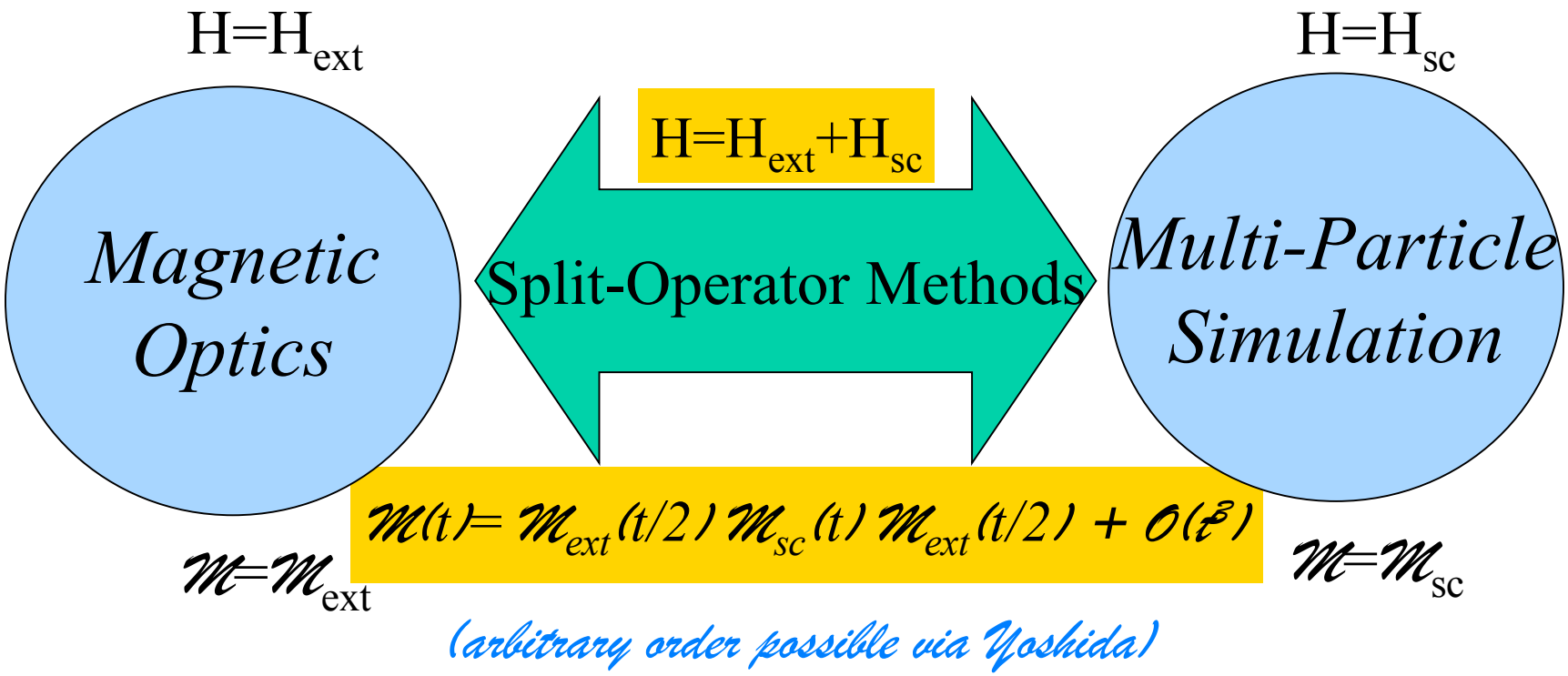
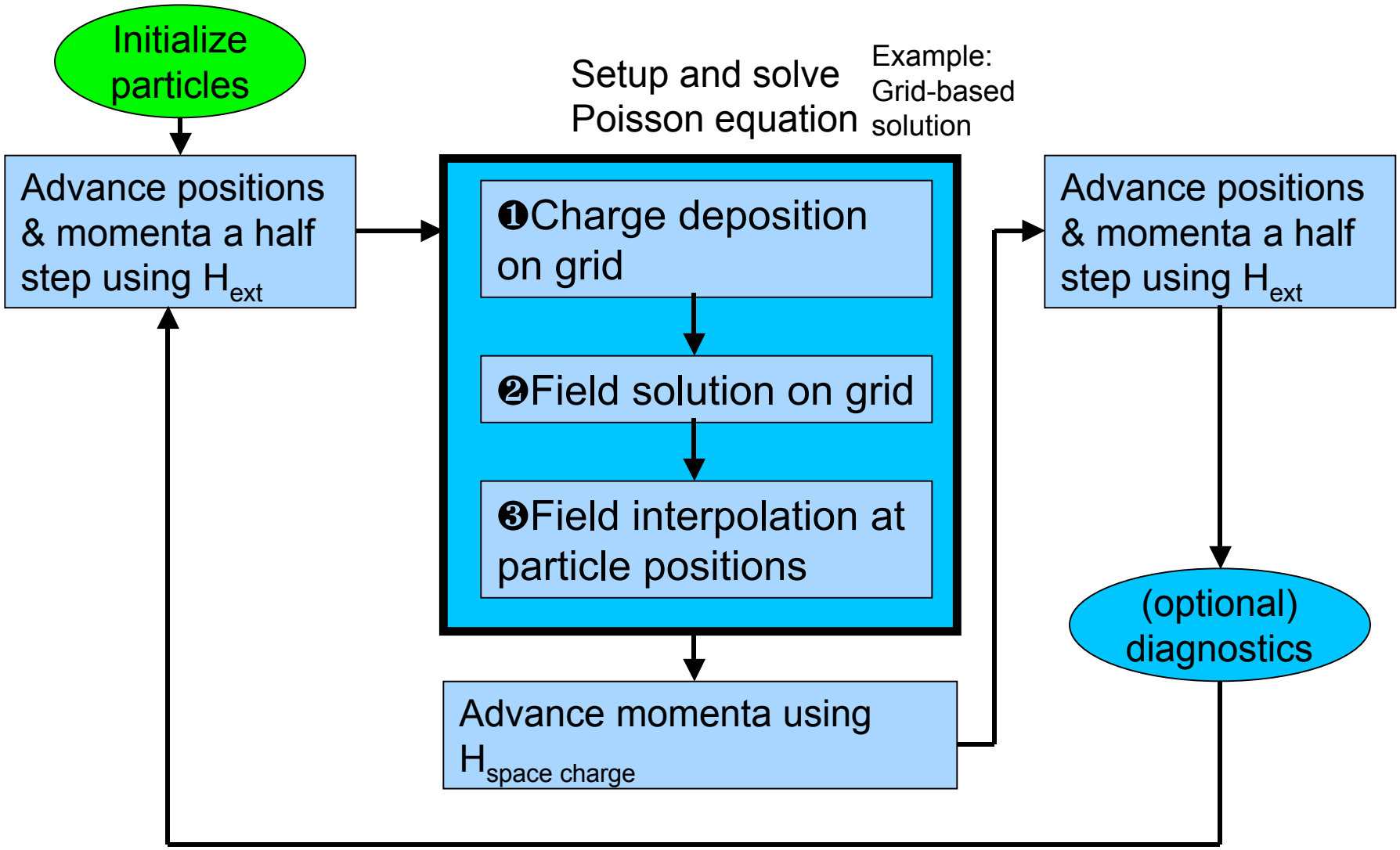
Split-Operator Approach



- **Philosophy:**
  - Do not take tiny steps to push ~ 100 million particles
  - Do take tiny steps to compute maps; then push particles with maps

Particle-In-Cell (PIC) Simulation



Present Status of IMPACT

- **Since late 1990s has been developed and maintained by Ji Qiang. Many enhancements:**
- **Two particle-advance algorithms:**
  - Linear map based on H
  - Nonlinear Lorentz force integrator (using z/t as independent variable)
- **External beamline elements:**
  - Quad, dipole, rf cavity, solenoid+rf cavity, 3D constant focusing
  - DTL, CCDTL, CCL, SC cavity, user-defined element
- **3D space charge with 6 types of boundary conditions**
- **For error studies: gradient, misalignment, rotation errors**
- **Restart function and dynamic load balance**
- **Code suite: 3D envelope code, design code, IMPACT**
- **Used to study many problems: SNS linac, CERN SPL, LEDA, JHF linac, space-charge driven resonances,…**

Future Directions

- **New Poisson solvers for beams with large aspect ratios**
- **Beam dynamics in rings**
  - IMPACT space-charge routines and rf cavity model embedded in MaryLie ("MaryLie/IMPACT")
    - ✔ Nonlinear symplectic maps for beamline elements
    - ✔ Nonlinear symplectic and nonsymplectic tracking
    - ✔ Fitting and optimization
- **Modeling high-brightness electron beams**
- **Multiple species**
- *Multiple reference particles* **to handle situations where the motion is too nonlinear to be represented by just one reference particle**